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A PARAGENETIC CLASSIFICATION OF THE MAGNET COVE MINERALS

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INTRODUCTION

Specimens of lodestone, aegirite, eudyalite and other minerals from Magnet Cove, Arkansas, have found their way into collections all over the world. Yet there have been no general mineralogical papers written on this area since the classical report by J. F. Williams.[1] Williams' petrographic, mineralogic, and crystallographic descriptions, coupled with the work of others which he incorporates in his report, leaves little to be added in those fields. However, the problems of petrogenesis and mineral genesis were covered with far less detail. Contributions to the petrogenesis of the Magnet Cove area were made by H. S. Washington in the first years of the present century.[2] The present paper will make a few comments on the character of the intrusion and on the origin of the minerals.

Magnet Cove lies in southwest central Arkansas in the Ouachita Mountains physiographic province near its southeastern border where the strongly folded Paleozoic sediments disappear beneath the Cenozoic sediments of the Gulf Coastal Plain (Fig. 1). A good highway connects the area with the city of Hot Springs, which lies about 12 miles to the west. The writer visited the area in the summer of 1929, accompanied by Prof. G. L. Knight. Mr. J. W. Kimzey of Magnet was of great assistance through his kindness in directing us to the localities where the best collecting could be found. The writer is very grateful to George C. Branner, State Geologist of Arkansas, for helpful suggestions during the preparation of the manuscript.

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[1] *Ark. Geol. Survey, Ann. Rept.*, **1890,** Vol. 2, pp. 163–343.

[2] Igneous complex of Magnet Cove, Arkansas: *Bulletin Geol. Soc. Am.*, Vol. **11,** pp. 389–416, 1900. The Foyaite-Ijolite series of Magnet Cove; A chemical study in differentiation: *Jour. Geol.*, Vol. **9,** pp. 607–622; 645–670, 1901.

The Magnet Cove intrusive complex is elliptical in plan with a maximum diameter of about 15,000 feet. The more resistant peripheral intrusives form a rim which surrounds the cove or basin. The rim is broken through only at the northern and southwestern portions where the narrow valley of Cove Creek crosses the complex. The floor toward the center of the cove is relatively flat except for a 50-foot hill of calcareous and siliceous tufa in the west central portion. Another tufa mass lies to the west across Cove Creek. The hills composing the rim of the cove are densely wooded while the cove floor is cultivated, so bed rock exposures are extremely discontinuous. This renders difficult any attempt to study the structural relationships of the igneous and sedimentary rocks.

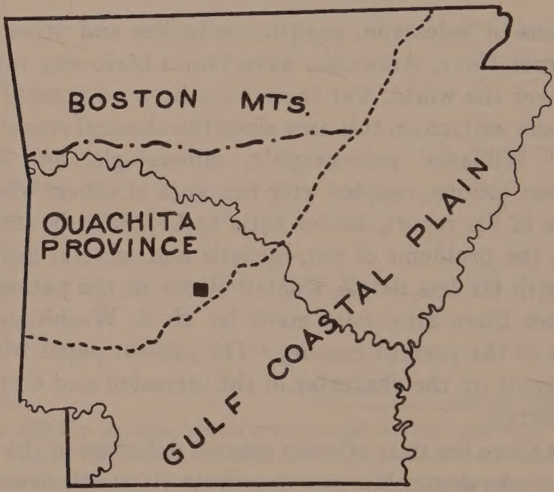

Fig. 1. Index map of Arkansas showing location of Magnet Cove.

The sedimentary rocks in the Magnet Cove area are Upper Devonian and Lower Mississippian in age. The oldest rocks belong to the Arkansas novaculite formation and consist of novaculite and interbedded shale. The novaculite beds are resistant to erosion and form ridges which are very prominent north and east of the cove. Overlying the novaculite formation are the Hot Springs sandstone and Stanley formations of Lower Mississippian age. The Stanley formation is largely shale, but with some sandstone. The igneous rocks are definitely intruded into the sedimentary series, and consequently are younger in age. The alkalic intrusions found here and elsewhere in Arkansas have been referred to the mid-Cretaceous,[3] but from the local evidence one can only say that the Magnet Cove complex is post-Stanley.

PETROGENESIS

The general distribution of the igneous, sedimentary and metamorphic rocks of Magnet Cove is shown on the accompanying map (Fig. 2). The distribution of the various types of igneous rocks may be seen on the original map by Williams or on a corrected map published by Washington.[4] A large part of the floor of the cove is covered by alluvium and the two tufa hills already described. Igneous rocks crop out at a number of places, especially in the southern part of the basin. The rim of the cove is composed of sedimentary rock, in a large part metamorphosed, and an outermost broad circular band of igneous rocks. Beyond occur the normal sedimentary rocks of the area (shales, sandstones, and novaculites) with a few small dikes. Williams[5] refers to the nephelite-syenite of the basin as the "cove" type, whereas the nephelite-syenite outcropping around the periphery of the complex is called the "ridge" type. Of utmost interest is the occurrence of scattered bodies of metamorphosed calcite inside the cove. The presence within the peripheral intrusives of exposures of metamorphic rock elongated parallel to the edge of the complex should also be noted.

The igneous rocks are alkaline and include such species as ijolite, shonkinite, foyaite, monchiquite, and tinguaite. According to Washington the rocks become decreasingly basic between the center and the periphery of the complex.[6]

THEORY OF WILLIAMS. Williams states that the igneous rocks may be divided into three genetically distinct groups:[7] (1) The oldest intrusives, which are basic, nephelitic, abyssal rocks. They are holocrystalline and around the edges are porphyritic. Their outcrop is confined to the interior of the cove, except for dike offshoots. (2) Monchiquitic rocks which were injected into contraction cracks in the abyssal rocks. (3) The nephelitic and leucitic rocks of the cove

[3] Croneis, Carey, and Billings, Marland, New areas of alkaline igneous rocks in central Arkansas: *Jour. of Geology*, Vol. **37**, No. 6, pp. 542–561, 1929. Miser, H. D., New areas of diamond-bearing peridotite in Arkansas: *U. S. Geol. Survey*, Bull. **540**, pp. 534–546, 1912.

[4] *Bull. Geol. Soc. Amer.*, Vol. **11**, p. 389, 1900.

[5] *Op. cit.*

[6] *Op. cit.*, p. 403.

[7] *Op. cit.*, pp. 342–343.

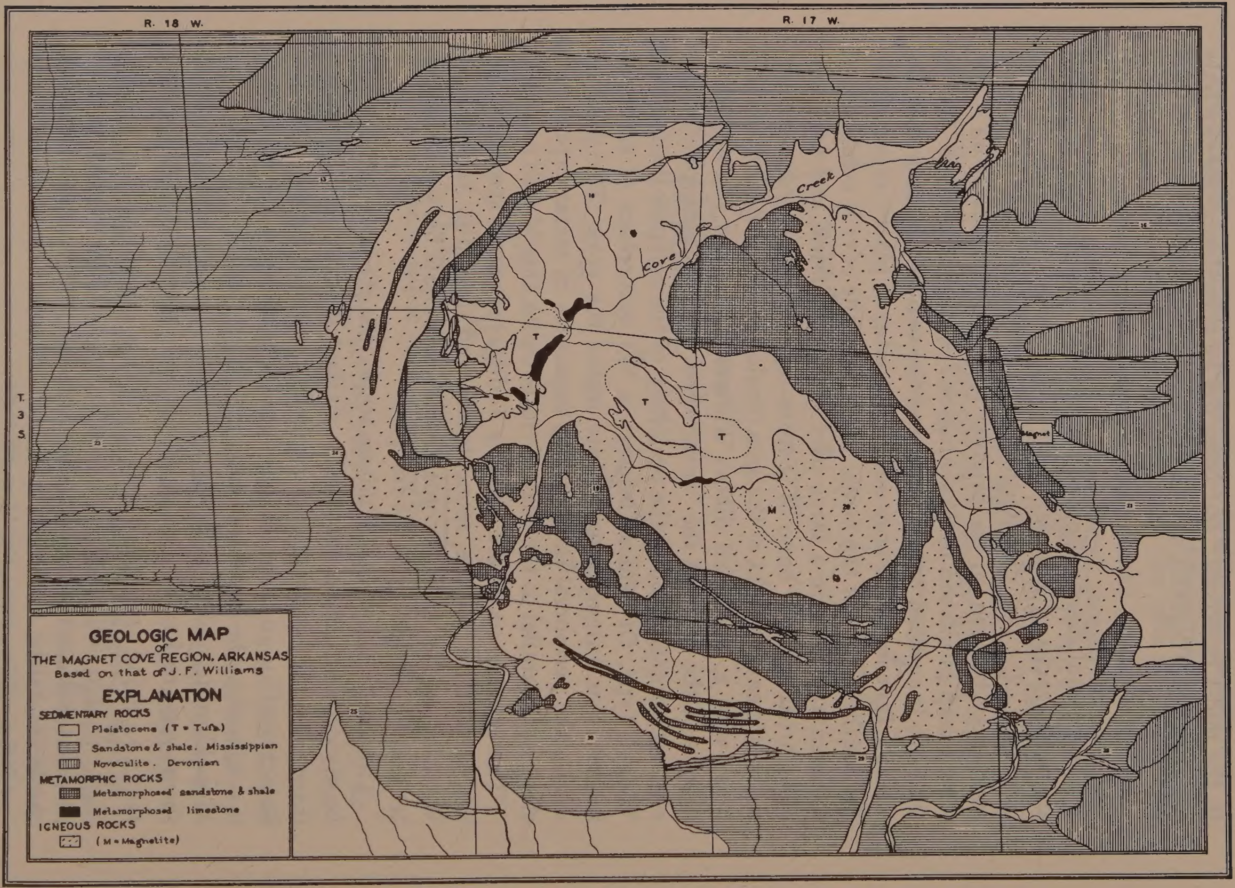
R. 18 W.
R. 17 W.
T. 3 S.
Cove
Creek
Magnet
T
T
T
M
GEOLOGIC MAP
of
THE MAGNET COVE REGION, ARKANSAS
Based on that of J. F. Williams
EXPLANATION
SEDIMENTARY ROCKS
Pleistocene (T = Tufa)
Sandstone & shale. Mississippian
Novaculite. Devonian
METAMORPHIC ROCKS
Metamorphosed sandstone & shale
Metamorphosed limestone
IGNEOUS ROCKS
(M = Magnetite)

FIG. 2.

rim and the tinguaitic dikes. These rocks cut the rocks formed in the two earlier periods of intrusion.

Williams gives no views in regard to the structure of the complex other than to say that all of the igneous rocks are intrusive in form. In regard to the metamorphosed calcite he states that the coarse crystals were formed either by contact action of igneous rock on common limestone, or, since limestone is not found in the local column, through contact with local hot spring deposits.[8]

THEORY OF WASHINGTON.[9] Washington doubts Williams' thesis of three distinct groups of rocks and three distinct periods of intrusion. He believes that the igneous complex was formed through ". . . a single intrusion of magma, which differentiation had split up into two main groups of central, basic, ijolitic rocks and peripheral, less basic syenites, the monchiquitic and tinguaitic dikes being both contemporaneous and subsequent injections of these differentiates into the cracked cover and cooled igneous mass and surrounding rock." It is suggested that the igneous body is a laccolith with the shape of a thick disk. Evidence given by Washington supporting the laccolithic theory follows.[10]

1. The broadly elliptical shape of the area, surrounded by shales and sandstones.
2. The quaquaversal upturning and the metamorphism of the contiguous shales at many places along the border.
3. The existence of a zone of what is apparently highly metamorphosed shale along the highest parts of the ridge and elsewhere on the outer slope, representing the remains of the original cover.
4. A platy parting approximately parallel to the walls, which has been developed in place in the foyaite.
5. The serial arrangement of the various igneous rocks from the center outward and concentric with the general border of the igneous area.
6. The, on the whole, regular change in structure and size of grain from the center to the periphery.

The outcrops of metamorphosed calcite are omitted from Washington's map and no discussion is given in either of his papers as to the origin of this material.

THE WRITER'S VIEWS. It is the writer's opinion that the metamorphosed calcite deserves more attention than has been paid it by previous investigators. It is important for the following reasons: 1. Contained within it is an important group of contact metamorphic minerals. 2. It may have had an effect upon the chemical composition of the magma, as suggested by Shand: "Both nephelite and leucite are or were developed in these rocks which show an increasing proportion of magnesia and lime toward the center of the area, where several masses of contact altered limestone have been found."[11] 3. The origin of this limestone may throw some light on the mechanics of the intrusion.

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[8] *Op. cit.*, p. 181.

[9] Washington, H. S., Igneous complex of Magnet Cove, Arkansas: *Bull. Geol. Soc. America*, Vol. **11**, pp. 389–416, 1900. The foyaite-ijolite series of Magnet Cove; a chemical study in differentiation: *Jour. Geol.*, Vol. **9**, pp. 607–622; 645–670, 1901.

[10] *Bull. Geol. Soc. Amer.*, Vol **11**, p. 396, 1900.

The suggestion of Williams that the limestone may be a local tufa deposit is untenable, because tufa deposits are superficial whereas the grain of the metamorphosing igneous rocks is evidence of intrusion at some depth. Perhaps Williams meant a tufa deposit interbedded with the Mississippian sediments, but that would be a very remarkable coincidence for no such deposits have been reported occurring elsewhere in the vicinity. According to the stratigraphic column given below limestones are absent from the formations outcropping in the Magnet Cove area. The nearest limestone lies at a stratigraphic depth of 3,500 to 4,000 feet in the Womble formation (Devonian) while more limestones appear in the still older rocks.

Calcite dikes, associated with intrusions of granite and nephelite syenite, have been reported by various writers, most recently by Osborne.[12] But the purity of the Magnet Cove calcite in respect to other possible igneous minerals argues strongly against a magmatic origin for this material.

The best suggestion that the writer can make in regard to the origin of the metamorphosed calcite is that it was originally part of a limestone bed and has been carried up by the magma a distance of several thousand feet. Powers records among other instances one in which inclusions in stock-like masses in the Crazy Mountains had been apparently carried up a stratigraphic distance of four miles.[13] A stock of nepheline rocks in Sekukuniland, Transvaal, a little over six square miles in area encloses a block of limestone nearly half a mile square. A similar condition exists in the Fen District, Norway, except that the stock is smaller and the enclosed limestone block is relatively much larger.[14]

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[11] Shand, F. J., *Eruptive Rocks*, p. 232.

[12] Osborne, F. F., The nepheline-gneiss complex in Dungannon Township, Ontario, Canada: *Am. Jour. Science* (5), Vol. **20,** pp. 33–60, 1930.

[13] Powers, Sidney, The origin of inclusions in dikes: *Jour. of Geol.*, Vol. **23,** p. 179, 1915.

[14] Shand, F. J., *Op. cit.*, p. 231.

SURFACE AND SUBSURFACE STRATIGRAPHY AT MAGNET COVE, ARK.

Data from Croneis, *Ark. Geol. Survey Bull.* 3

Period	Formation	Thickness	Character
Mississippian	Stanley formation	6000+ ft.	Shale and sandstone. Novaculite conglomerate near base.
	Hot Springs sandstone	200+	Quartzitic sandstone.
Devonian	Arkansas novaculite	950±	Novaculite and shale.
Silurian	Missouri Mt. "slate"	300	Shale and slate.
	Blaylock sandstone	1500	Compact sandstone and shale.
Ordovician	Polk Creek shale	200	Black graphitic shale.
	Bigfork chert	700	Chert and shale.
	Womble formation	1000±	Clay shales and limestone.
	Blakely sandstone	550±	Sandstone and shale.
	Mazarn formation	1000±	Clay shale, sandstone, and limestone.
	Crystal Mt. sandstone	850±	Sandstone.
Cambrian ?	Collier shale	300±	Clay shale and chert. Limestone near top.

The writer believes that evidence is more favorable to the intrusive body being a stock than a laccolith for the following reasons:

1. In the usual concept of a laccolith the neck is constricted, which would impede the upward movement of large inclusions.
2. According to the laccolith hypothesis the structure in the vicinity of the igneous mass should be anticlinal. Instead the region is one of close folds (Fig. 3), and apparently "the adjacent sedimentary rocks have not been greatly disturbed by the intrusion."[15]
3. With one exception the points enumerated by Washington in favor of laccolithic shape and differentiation *in situ* could apply equally well to a stock. In fact, Washington states: "The question whether the mass is a true laccolith, as it seems to be, or a stock or other form of intrusive mass is, after all, of secondary importance.[16] The point which would not apply equally well to a stock is the

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[15] Branner, George C., Informal communication.

[16] *Op. cit.*, p. 398.

third one, namely the presence of highly metamorphosed shale ("hornstone") along the highest parts of the ridge which is supposed to represent remains of the original cover. But these hornstone outcrops are elongated and are arranged in a parallel manner to each other and to the periphery of the complex. It is inconceivable to the writer that the forces of erosion could so act upon a laccolithic cover as to leave remnants of this elongated shape and parallel orientation. It is much more probable that the hornstone outcrops are truncated edges of steeply-dipping strata into which the peripheral intrusives were injected in a roughly conformable manner. Williams noted a sill intruded between layers of sandstone[17] and the tendency of the dikes to parallel the strike of the sedimentary rocks.[18]

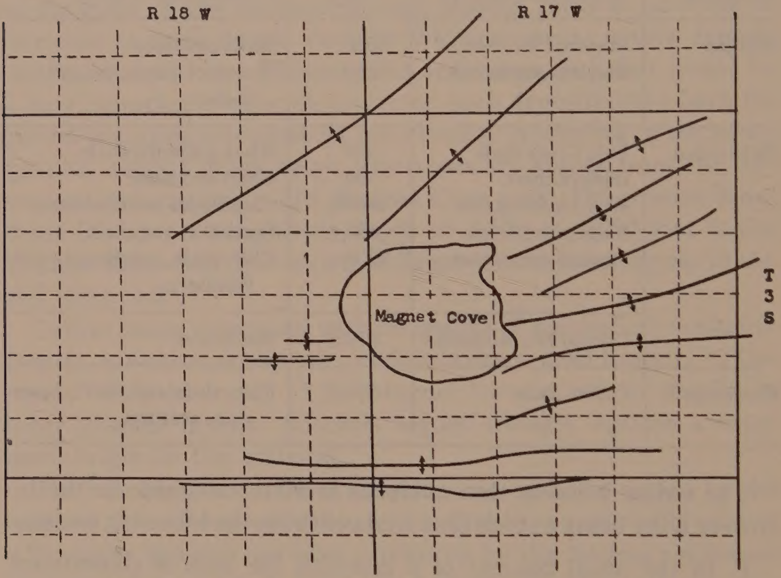

FIG. 3. Map of anticlines in Magnet Cove area. Map furnished by George C. Branner. Data from L. S. Griswold's report on the novaculties of Arkansas (*Ark. Geol. Survey*, vol. 3, 1890).

The writer suggests the following sequence of events in the Magnet Cove area:

1. Close folding of the Paleozoic sediments.

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[17] *Op. cit.*, p. 177.
[18] *Op. cit.*, p. 198.

2. The intrusion of a mass of alkaline magma containing inclusions of limestone obtained from deeper sediments.
3. Differentiation of this magma, producing the various types of igneous rock occurring in the cove interior. Assimilation of limestone may have played a part in this process as suggested by Shand.
4. Intrusion of the peripheral igneous mass which probably was an acidic differentiate of the magma filling the main stock. The shape of the igneous body was strongly influenced by the structure of the sedimentary rocks.
5. Differentiation of the peripheral intrusive mass.
6. Differential erosion, producing a topographic basin, and hot spring deposition on the floor of the cove.

The smaller dikes were intruded into the already crystallized igneous rocks and into the country rock at various periods during the differentiation and solidification of the magma. In places the magma dragged up the strata producing local dips away from the complex.

MINERALS

The chemical character of the magmas has been fully described by Washington.[19] The igneous rocks contain no quartz, but do contain abundant potash feldspar and nephelite, showing that the original magma was relatively low in silica and high in alkalies. The only occurrence of free silica is near Magnet where contact metamorphism has caused the formation of quartz crystals in country rock sandstone. But it is probable that the silica in this case was dissolved in part at least from the sandstone and then reprecipitated by the magmatic waters. The most unusual feature at Magnet Cove is the high titanium content of the rocks. This element is an essential constituent of astrophyllite, ilmenite, schorlomite, titanite, dysanalyte, brookite, and rutile. Some of these minerals are found as primary constituents of the igneous rocks while others are contact metamorphic products. Evidently both the original magma and the escaping solutions were unusually rich in titanium.

About 42 distinct mineral species have been reported from Magnet Cove. These may be classified into the following groups: igneous, contact metamorphic, and secondary. Further division is possible within each group.

IGNEOUS MINERALS. These are divided into three subgroups depending upon the type of containing rock.

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[19] *Op. cit.*

(a) Cove intrusives. These rocks consist of ijolite and biotite-ijolite (Washington's classification). Specimens of *magnetite* derived from an underlying magnetite-rich bed rock may be found in great abundance loose in the soil in the central part of the cove. They are invariably coated with limonite. About one per cent possess polarity. The presence of lodestone gave the locality its name and the magnetite bodies of this vicinity have a decided effect on the magnetic needle, which may explain why the section lines are so irregular. Kimzey has noted that the magnetite in the igneous rock immediately beneath the soil does not possess polarity.[20]

Beautiful specimens of a coarse nephelite schorlomite syenite are obtainable near the center of the cove south of an old church building. This rock is dominantly *nephelite* in oily salmon colored masses and *schorlomite*[21] in large and irregular shiny black anhedrons. A third important constituent is *biotite* occurring in scattered books.

Other primary minerals found in the Cove series follow:

melanite
apatite
brookite
pyrite
diopside
orthoclase
titanite
ilmenite

(b) Ridge intrusives (foyaite, shonkinite, leucite-porphyry). A new road cut along the state highway between Hot Springs and Magnet offers fresh exposures of the peripheral intrusives on the west side of the cove. The syenite exposed here is both fine and coarse grained. Specimens of the coarse syenite contained gray prismatic *orthoclase* crystals up to two inches in length and subordinate smoky colored *nephelite*, small scattered crystals of *pyrite*, and *fluorite* in minute purple colored grains. The rock is gray in color due to the dominance of orthoclase. Other minerals in the ridge intrusives are:

diopside
magnetite
apatite
ilmenite
titanite
rutile
aegirite

(c) Dike rocks (including pegmatite, tinguaite, monchiquite, and fine-grained prophyries). Alkaline pegmatite in contact with coarse calcite is well exposed in fragments of rock blasted out of the highway immediately west of Cove Creek bridge. The rock is a very coarse aggregate of black prismatic *aegirite*[22] crystals, white *microcline* euhedrons, and irregular masses of greenish *nephelite*. The crystals average between one and two inches in maximum dimension. In partially weathered specimens of this rock decomposition of nephelite has released terminated microcline crystals. The microcline did not exhibit the usual twinning. Determination was made by means of the extinction angle on basal sections. Bright pink and glassy grains of *eudialyte* occur with the aegirite; most often the two minerals are actually touching. *Astrophyllite* in brownish yellow plates completes the list of important pegmatite minerals.

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[20] Informal communication.

[21] Koenig, G. A., Schorlomite, a variety of melanite: *Proc. Phil. Acad. Nat. Sci.*, **1886,** p. 355.

Williams describes leucitic dike rocks in which "pseudoleucite" is a most important constituent.[23] *Pseudoleucite* is a pseudomorph after leucite and is composed of radiating orthoclase crystals mixed with nephelite and in some instances aegirite. Williams considers that leucite began to form and that a change in conditions caused a recrystallization and separation into nephelite and orthoclase. Bowen[24] states that pseudoleucite is formed through reaction between leucite crystals and surrounding liquid. Other minerals reported from the dike rocks follow:

melanite
wollastonite
titanite
magnetite
ilmenite
biotite
augite
olivine
amphibole
plagioclase

CONTACT METAMORPHIC MINERALS. Mineralizing solutions given off by the intruding magma metamorphosed both the shale and sandstone country rock and the limestone xenoliths.

(a) Contact metamorphic minerals in shale. Most of the shale inside the periphery of the complex has been metamorphosed to "hornstone." According to Williams this alteration was accompanied by the formation of *feldspar*, *pyrite*, *magnetite*, and *biotite* in the country rock.[25]

(b) Contact metamorphic minerals in sandstone. At the town of Magnet alkaline syenite is intruded in a beautiful white sandstone. Solutions expelled by the magma caused the formation of large crystals of smoky, milky, and colorless *quartz* in aureoles in the sandstone. The crystals are in some instances arranged in parallel aggregates. Subsequent to the period of quartz formation the solutions given off by the intruding magma deposited *brookite* in relatively small crystals perched upon the faces of the quartz crystals. *Rutile* and *hematite* accompany the brookite, but in much lesser abundance.

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[22] Washington, H. S., and Merwin, H. E., The acmitic pyroxenes: *Am. Mineral.*, **12**, 1927, p. 243.

[23] *Op. cit.*, pp. 268–274.

[24] Bowen, N. L., *Evolution of Igneous Rocks*, p. 245, 1928.

[25] *Op. cit.*, pp. 296–300.

(c) Contact metamorphic minerals in calcite. The metamorphosed calcite is very coarsely crystalline and is cut by fine-grained dikes and pegmatite. It is beautifully exposed by a recently excavated road cut immediately west of the Cove Creek bridge and the collecting possibilities at the time of the writer's visit could not be excelled.[26] All of the calcite observed contained contact metamorphic minerals. It is a thesis of this paper that there were two periods of metamorphism of the calcite. The first took place while the limestone xenoliths were being carried up by the magma to their present position. This mineralization was similar to that at Vesuvius, where limestone bombs were metamorphosed while they were passing up through the conduit of the volcano. At Magnet Cove the calcium carbonate recrystallized and the blocks were penetrated by solutions from the surrounding magma which caused the formation of contact metamorphic minerals. The second mineralization occurred when the frozen-in calcite bodies were cut by later dikes, especially by the alkaline pegmatite. The intrusion of this latter body caused metamorphism immediately adjacent to the contact, but not for any distance into the limestone. A reaction zone occurs between the two which consists of an outer yellow band and an inner white band. The yellow band ranges from one-half to one inch in thickness while the white band ranges from one-fourth to one-half inch.

The xenolithic rock which has not been metamorphosed by later dikes consists of coarsely crystalline gray *calcite* with isolated patches and veins of fine granular *monticellite*. The monticellite is yellowish brown and glassy when fresh, but in weathered specimens it is brown and earthy. *Magnetite* is disseminated through the calcite in grains up to one-half inch in diameter. Many of these have a spheroidal shape. *Dysanalyte* (or *perovskite*) may also be present in glossy black crystals which are a combination of the forms (100) and (111). *Wollastonite* occurs both in patches of radiating yellowish white needles and in irregular veins, which also contain small striated *pyrite* cubes. *Vesuvianite* was observed in aggregates of yellow green crystals, some nearly an inch across. Eightlings of *rutile* occur in soil derived from the weathering of a metamorphosed calcite mass.

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[26] Other localities are mentioned by Haltom, Wm. L. Magnet Cove, Arkansas, and vicinity: *Am. Mineral.*, **12**, 484–487, 1929.

The contact metamorphic minerals formed by the intrusion of the alkaline pegmatite dike into the coarse calcite are confined to the narrow reaction zone along the contact. The outer band (yellow) is a mixture of calcite and minute yellow scales of *mica* (probably phlogopite). The inner band (white) is composed of acicular *wollastonite*. It lies in direct contact with the chilled zone of the pegmatite dike which contains relatively small crystals and masses of nephelite, aegirite, and eudialyte. Dark greenish- or reddish-brown masses composed of minute fibres of *thomsonite* are likewise found in this zone and are very likely the result of reaction between dike and wall rock, for they do not occur in the coarse pegmatite.

SECONDARY MINERALS. Some of the minerals in this class were formed by supergene alteration of primary minerals, but a number are undoubtedly due to alteration by hydrothermal solutions given off by the crystallizing magmas. The group is divided into:

(a) Minerals formed through the alteration of igneous minerals. *Epidote*, hitherto unreported from Magnet Cove, was observed in a felted mass coating large microcline crystals. The feldspar immediately beneath was epidotized for a short distance, but this replacement did not destroy the cleavage of the spar. *Maganopectolite* occurs in the alkaline pegmatite in glassy masses with rectangular outline surrounded by brown manganese oxide. The pectolite is probably a replacement but the writer found no clue as to the identity of the original mineral. Eudialyte alters to yellow glassy *eucolite* which in turn alters to *catapleiite*, according to Foshag.[27] Other minerals derived from primary igneous minerals are:

protovermiculite
cancrinite
calcite
kaolinite
limonite
leucoxene
hematite
natrolite[28]
biotite

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[27] Foshag, W. F., Catapleiite from Magnet Cove, Ark. *Am. Mineral.*, **8**, 70–72, 1923.

[28] Melville, W. H., Natroline from Magnet Cove, Ark. *U.S.G.S.*, Bull. **90**, p. 38, 1892.

(b) Minerals derived from primary contact metamorphic minerals:

rutile, in paramorphs after brookite[29]
hydrotitanite
limonite
chlorite
calcite

(c) Minerals in the tufa. The tufa is both calcareous and siliceous and was not deposited until erosion had carved out the basin and ridge. It antedates, however, the present position of Cove Creek, as this stream divides two tufa deposits that were probably at one time continuous. The position of the tufa in respect to the limestone is highly suggestive. Hot springs located in the cove leached calcium carbonate from the limestone xenoliths and silica from the other rocks and deposited these compounds upon reaching the surface. The same waters may have dissolved *magnetite* from the lower rocks and redeposited it in the tufa.[30]

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[29] Williams, *op. cit.*, p. 320.
[30] Williams, *op. cit.*, p. 335.

THE GARNETS IN THE GLAUCOPHANE SCHISTS OF CALIFORNIA

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Abstract

It is shown that the garnets of the glaucophane schists of California are nearly uniform in composition. The dominant constituent is almandite. Grossularite, pyrope and andradite are also present. These garnets lie within the group called "eclogite-garnets" by Eskola. One new garnet analysis is reported.

Introduction

Among the characteristic minerals of the glaucophane schists in the California coast ranges are the garnets. The glaucophane schists appear in many small detached areas and the outcrops often consist only of isolated boulders so that it is extremely difficult to ascertain their relation to other rocks. The schists are most variable in appearance and composition and garnets occur in them only sporadically in patches or in zones paralleling the schistosity. Still, garnets were found in at least a few spots in each of the areas of glaucophane schist visited. Though the garnets are most typically associated with glaucophane they occur in a few places in rocks consisting largely of actinolite or of omphacite. It was doubtless this fact that led several early writers[1] to refer to some of these rocks as eclogites or glaucophane-eclogites.

So far there has been available only one partial analysis of one of the garnets in these rocks[2] and no information whatever as to their physical properties. The basis for the statement by Professor Eakle[3] that the garnet in the schist of the Tiburon Peninsula is andradite is not known to the writer. The composition of these garnets is shown in Table II.

Garnetiferous glaucophane schists are known in a number of other regions, but the available data on their garnets is most scanty. They are usually described only as being red and occurring in dodecahedrons. Luedecke[4] in describing the garnets in the glaucophane schists of Syra mentions only that they give a bead test for iron and have a hardness of 7.5. Later descriptions of these rocks give no information at all.

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[1] Holway, R. S., Eclogites of California: *Journ. Geol.*, vol. **XII**, pp. 344–358, 1904; Murgoci, G., II.—On some glaucophane schists, syenites, etc. *Univ. Calif. Publ. Bull., Dept. Geol. Sci.*, vol. **IV**, pp. 359–396, 1906; Smith, J. P., The paragenesis of the minerals in the glaucophane-bearing rocks of California; *Proc. Am. Phil. Soc.*, vol. **XLV**, pp. 183–242, 1907.

[2] Smith, J. P., *op. cit.*, p. 202.

[3] Eakle, A. S., Minerals of California: *Bull.* **91**, *Calif. State Mining Bureau*, p. 173, 1923.

On the Isle de Groix there are also garnet-bearing glaucophane rocks. The only mention of their character known to the writer is a remark by Mlle. Y. Briere[5] that "almandite" occurs on Groix in a glaucophane—epidote rock. Other descriptions of similar rocks lack any specific references to garnets. An analysis of a garnet from an undescribed glaucophane schist from New Caledonia is quoted in Table I.

Eskola, in his paper on the facies classification of rocks,[6] proposes a subfacies of his "eclogite facies" of metamorphic rocks which comprises the rocks here considered. He says in part:

> Another facies closely related to that of eclogite is one characterized by eclogite-garnet, glaucophane, lawsonite and paragonite (?). It might be designed [sic] as the hydrated eclogite facies and probably belongs to a region of somewhat lower temperature. These remarkable rocks are associated with eclogites and jadeitites on the island Syra, in the Alps and in California.

In describing the eclogite facies Eskola says:[7]

> The eclogite-garnets present an isomorphic series of almandite and pyrope in all proportions uptil 75 mol. per cent pyrope, and with small amounts of grossularite.

He does not give any evidence for the statement that the garnets of glaucophane rocks are "eclogite-garnets."

The analyses given in Table I are not entirely comparable because the same constituents have not been determined in each case. In the main the analyses are very similar. The ratio of the oxides has not been calculated for analysis II as it shows a great excess of ferrous iron. This is doubtless due to the nondetermination of the ferric iron and in using this analysis for Table II an arbitrary adjustment has been made by recalculating a part of the ferrous iron to ferric iron. The marked departure of the ratio, $RO:R_2O_3:SiO_2$, for analysis I from the theoretical value, 3:1:3, need not alarm one.

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[4] Luedecke, O., Der Glaukophan und die Glaukophan führenden Gesteine der Insel Syra: *Zeit. d. deut. geol. Ges.*, vol. **28**, pp. 270 and 274, 1876.

[5] Briere, Mlle. Y., Les Eclogites francaises—leur composition mineralogique et chimique: leur origine. Thesis, Faculte Sci., *Paris*, p. 84, **1920**.

[6] Eskola, P., The Mineral Facies of Rocks: *Norsk Geologisk Tidskrift*, vol. **6**, p. 176, 1920.

[7] *op. cit.*, p. 171.

TABLE I. ANALYSES OF GARNETS FROM GLAUCOPHANE ROCKS

	I	II	III
SiO_2	38.26	38.69	38.15
TiO_2	0.00	—	—
Al_2O_3	19.93	19.10	22.18
Fe_2O_3	4.87	—	—
FeO	20.40	26.81	21.26
MnO	0.04	—	5.54
MgO	3.94	5.07	4.74
CaO	12.02	10.64	7.78
H_2O-	0.48	—	
H_2O+	00.12	—	ig. loss 0.31
	100.06	100.31	99.96
$RO:R_2O_3:SiO_2$	2.65:1:2.83	—	2.90:1:2.92
Sp. Gr.	3.821	3.818	4.011

I. Garnet from glaucophane schist collected by Professor G. D. Louderback near mouth of Russian River. Analyst, A. Pabst.

II. Garnet from "eclogite" on Coyote Creek, about 6 miles north of San Martin, Santa Clara County. Analyst, W. O. Clark. In J. P. Smith, *Proc. Am. Phil. Soc.*, vol. **XLV**, p. 194, 1907.

III. Garnet in glaucophane schist, Balade Mine, New Caledonia. Analyst, A. Liversidge, *Journ. & Proc. Roy. Soc. N. S. W.*, vol. **14**, p. 242, 1880. Occurring in a rock with glaucophane, quartz, epidote and white mica. No petrographic description is given.

A similar excess of R_2O_3 is not uncommon in garnets. Seven of twelve new analyses of garnets given by Eskola[8] depart in the same sense. This feature of garnet analyses has been discussed by Phillipsborn[9] and he suggests that it may not indicate analytical error.

Titanium was tested for only in the first garnet. The writer also tested garnets A and B of Table II. Only one yielded a trace of titanium. These observations are in agreement with the statement by Eskola,[10] "all eclogite-garnets are low in titanium, a very remarkable feature."

Table II shows the molecular proportions of the several constituent molecules present in the garnets of Table I and in two other

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[8] Eskola, P., On the eclogites of Norway, Videnskapsselskapets Skrifter, I. *Mat.-Naturv. Kl.* No. **8,** Oslo, 1921.

[9] v. Phillipsborn, H., Beziehungen zwischen Lichtbrechung, Dichte und chemischer zusammensetzung in der Granatgruppe: *Sächs. Ak. Wiss. Abh. Mat.-Phys. Kl.*, vol. **XL,** No. 3, p. 34, Leipzig, 1928.

[10] *op. cit.*, p. 173.

TABLE II. CALCULATED COMPOSITION OF GARNETS IN MOL. PERCENTAGE OF END MEMBERS

	I	II	III	A	B
Grossularite	21	19	22	8	30
Andradite	15	10	n.d.	24	4
Almandite	48	51	47	48	56
Pyrope	16	20	19	20	10
Spessartite	—	n.d.	12	—	—

I. Same as table I.

II. Same as table I.

III. Same as table I.

A. Calculated from partial analysis of garnet in "eclogite" from Hilton Gulch, 5 miles east of Calaveras Valley, San Jose Quadrangle, described by J. P. Smith, *Proc. Am. Phil. Soc.*, vol. **XLV**, p. 202, 1907.

B. Calculated from partial analysis of garnet in glaucophane schist from the original lawsonite locality near Reed Station, Marin County, California.

garnets from California glaucophane rocks of which partial analyses were made. With the exception of the spessartite present in the garnet from New Caledonia all these garnets are very similar. Especially the proportion of almandite, the main constituent, varies but slightly.

TABLE III. COMPOSITION RANGES OF CERTAIN GARNETS AS FOUND BY DIFFERENT INVESTIGATORS

	Eclogite Garnets as found by Heritsch	Eclogite Garnets reported by Eskola	Garnets in Glaucophane rocks, Pabst
Number of analyses	6	4	4
Range of Grossularite	9–42%	9–20%	8–30%
Andradite	0–21%	3–11%	4–24%
Almandite	33–57%	26–61%	48–56%
Pyrope	19–37%	16–61%	16–20%
Spessartite	0– 3%	1– 2%	0– 1%

In Table III are given the ranges of variation of eclogite-garnets as found by Heritsch working with analyses from various sources,[11] as represented by the eclogite-garnets of Norway reported by Eskola, and as found by the writer for garnets from the glaucophane rocks of California. A comparison of the first two columns shows that there is a definite chemical group of "eclogite-garnets," though the range of variation is wide. The garnets of the glaucophane rocks fall entirely within this range and are especially characterized by the small variation in the percentage of their chief constituent, almandite.

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[11] Heritsch, F., Studien ueber den Chemismus der Granaten: *Neues Jahrb., Beilbd. A*, **LV**, p. 74, 1926.

The Physical Properties of the Garnets

As shown above there are three or four major constituents in the garnets of the glaucophane rocks. In order that they can be determined from physical measurements it is necessary to find two or three functions that vary in a suitable manner with changes in the percentage of each of the constituents. For garnets the following functions have been suggested: specific gravity, refractive index, dispersion, lattice constant, and relative intensities of certain lines in the X-ray diffraction patterns. Various writers have given diagrams for the graphical solution of such problems. All methods were tried for the identification of the garnets in the glaucophane rocks but they did not lead to any satisfactory results.

Table IV. Properties of Garnets in Glaucophane Schists and Related Rocks

Maximum size	Density of rock	Density of garnet	Refractive index, N_{Na}	Lattice constant
I 15 mm.	3.179	3.821	1.787±0.002	11.58Å±0.03Å
II 2.5 mm.	3.527	3.818	1.799±0.002	—
A 5 mm.	3.215	3.884	1.795±0.002	11.60Å±0.03Å
B 3 mm.	3.154	3.827	1.799±0.002	11.59Å±0.03Å
C 2 mm.	3.178	3.787	1.799±0.002	—
D 2 mm.	3.230	3.719	1.803±0.002	—
E 3 mm.	3.115	3.658[a]	1.805±0.002	—

[a] Probably low due to inclusion of alteration products.

I. Same as Table I.

II. Same as Table I. Determinations made on material kindly supplied by Professor A. F. Rogers from the original collections of the late Professor J. P. Smith.

A. Same as Table II.

B. Same as Table II.

C. Data for garnet in glaucophane schist near Junction School House, 2 miles southwest of Healdsburg, Sonoma County, California.

D. Garnet in glaucophane schist near Camp Meeker, Sonoma County, California.

E. Garnet in glaucophane schist north of Berkeley, in Contra Costa County, California.

The essential data are shown in Table IV. Several of the functions mentioned can be dropped as of no value in the present case. The comparison of intensities of lines in the diffraction patterns can only be used where notable differences are found. Mr. W. H. Dore kindly prepared powder diffraction patterns of garnets I, A and B. No difference was observable in the relative intensities of the several lines on the different patterns and lacking other material for comparison no use could be made of this method suggested by Stockwell.[12] The lattice constants, determined from the best alpha lines calibrated against lines of KCl mixed in the preparation, are nearly the same. This is not a good indicator of the proportions of almandite and pyrope as the lattice constants of almandite, 11.497Å[13] and pyrope, 11.446Å[14], are too close together.

The indices of refraction were determined by the dispersion method at constant temperature. The prism method, which sometimes allows greater precision, could not be used because the garnets are for the most part too dull and fractured. Though the method used permits the determination of the dispersion of the garnets the differences are within the limits of error and so the indices are given in the table for sodium light only.

The density determinations are useful for distinguishing pyrope and almandite but not for distinguishing grossularite, sp. gr. 3.530, from pyrope, sp. gr. 3.547.[15] Similar considerations apply to the indices of refraction.

This leaves the indices of refraction and the density as suitable indicators of the composition of garnets C, D, and E. These data are insufficient for defining a composition in a four component system. They merely determine a certain range of composition that can be read from the tetrahedral diagrams of Phillipsborn. Still the properties of all the garnets examined are so nearly alike that it seems fairly certain that the compositions of C, D, and E also fall within the range of the analyzed specimens.

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[12] This journal, vol. **12,** pp. 335 and 336, 1927.

[13] Menzer, G., Die Kristallstruktur der Granate; *Zeit. f. Krist.*, vol. **69,** p. 389, 1928.

[14] The value for pyrope is extrapolated from the constant and analysis of an impure pyrope given by Menzer, using his data for the other end members. This is necessary and possible because no pure pyrope is known but sufficiently pure examples of all the others are reported by Menzer. Stockwell uses the value 11.430Å for pyrope.

[15] Calculated from the extrapolated lattice constant.

ASSOCIATIONS AND HABITS OF THE GARNETS

The uniformity in chemical composition of these garnets is in harmony with the constancy of their habits and association. The garnets in the glaucophane rocks are always in distinct red dodecahedrons. No trace of any other form, no notably distorted forms, no anhedrons (except those due to alteration) and not one poikilitic garnet were found among the hundreds examined in the present study. The maximum and common size of the garnets from different rocks is 2 to 3 mm. except in a few cases (Table IV). Of course, the garnets are larger in the coarser rocks. The density of the rocks (Table IV) gives a measure of the proportion of garnet present, all other constituents being much lighter.

In the following are given brief notes on the rocks containing the garnets listed in Table IV:

I. Russian River. Coarse (0.30–0.50 mm. average diameter) groundweb of actinolite with some glaucophane fringes. Titanite in rough grains partly surrounding rutile. Garnets carry very fine undetermined original inclusions. Chlorite and white mica in patches, partly altered from garnet.

II. San Martin. Coarse (0.15–0.25 mm.) diablastic web of long needles of zoned omphacite, green core, colorless edge. Some epidote, less titanite, in part with rutile, and only traces of glaucophane present. Garnet apparently fresh but bordered here and there by a little chlorite, partly with zoned inclusions of omphacite.

A. Hilton Gulch. Diablastic web (0.20–0.30 mm.) of actinolite fringed with glaucophane. Epidote and titanite in part very coarse. Garnets partly fresh, partly altered to chlorite, carry some inclusions of the other rock minerals.

B. Tiburon. Coarse web (0.13–0.20 mm.) of glaucophane tending to diablastic texture. White mica, epidote and titanite abundant. The mica tends to be aggregated around the garnets which are fresh but crowded with very fine undetermined inclusions in the interior and having a cleaner border.

C. Junction School House, fine (0.02–0.03 mm.) schistose web of glaucophane and epidote traversed by zones of chlorite and a little white mica, magnetite and titanite. Garnets enclosed in chlorite halos and crowded with fine undetermined inclusions. Structures in the groundmass bend around the garnets.

D. Camp Meeker. Diablastic (0.10–0.15 mm.) glaucophane and actinolite dominant with some white mica, epidote, magnetite, titanite and rutile. Garnets clean but much altered to chlorite with some white mica.

E. Contra Costa County. Very fine (0.02–0.03 mm.) diablastic groundweb of glaucophane with epidote and a little titanite. Garnets originally clean but now traversed by fibrous chlorite veinlets and surrounded by coarse epidote filling former space. Some patches of chlorite.

A PYRRHOTITE-CUBANITE-CHALCOPYRITE INTERGROWTH FROM THE FROOD MINE, SUDBURY, ONTARIO

W. H. Newhouse, *Mass. Institute of Technology.*

Intergrowths of cubanite and chalcopyrite have been described from a number of localities by Schwartz[1] and Ramdohr.[2]

The origin of certain of these intergrowths is clearly due to the breaking down of a solid solution to form the two minerals. A solid solution forms at a temperature which experimental data[3] suggests is above 400°C. This solid solution becomes unstable at lower temperatures and with slow cooling breaks down into the two components.

The present note will serve to call attention to a more complex intergrowth of this general type which is found in ores from the Frood mine, Sudbury, Ontario.[4]

A double break down or unmixing in the series chalcopyrite-cubanite-pyrrhotite is indicated by the relations in polished sections of these ores.

The specimens examined contain the opaque minerals, magnetite, pyrrhotite, pentlandite, cubanite, and chalcopyrite. The proportion of each of the different minerals varies considerably in different specimens, but magnetite is present only in small amount in all.

Irregularly shaped masses of cubanite are found, but also chalcopyrite and cubanite form intergrowths of laths or bands of each mineral. The boundaries of the two minerals are usually sharp and straight. They may cut off sharply without narrowing and always end abruptly against the large irregular masses of pyrrhotite.

These relations are typical of those found in ores from other localities, which have been seen by the writer and have been described in the literature.

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[1] Schwartz, G. M., Chalmersite at Fierro, New Mexico, with a note on its occurrence at Parry Sound, Ontario: *Econ. Geol.*, **18,** 270–277, 1923.

Intergrowths of chalcopyrite and cubanite; Experimental proof of the origin of intergrowths and their bearing on the geologic thermometer: *Econ. Geol.*, **22,** 44–61, 1927.

[2] Ramdohr, Paul, Neue Mikroskopische Beobachtungen am cubanite (chalmersite) und Überlegungen über seine lagerstättenkundliche Stellung: *Zeit. prakt. Geol.*, 169–178, **1928.**

[3] Schwartz, G. M., *op. cit.*

[4] Thanks are due to C. E. Locke, Professor of Mining Engineering, Mass. Inst. of Technology for the material on which this note is written.

In addition to the pyrrhotite found as irregular masses apparently deposited earlier than the other sulphides, it also is found intergrown with cubanite. Some of the cubanite does not contain intergrown pyrrhotite, but where the two minerals form this relation, the pyrrhotite may be present to the extent of several per cent of the mass or rarely in small areas 25 or 50 per cent. The distribution and orientation of the pyrrhotite in the intergrowths is clearly controlled by the structure of the cubanite crystals. The blade-like masses of pyrrhotite are always narrow, with fairly sharp borders, and instead of always being straight like those of cubanite in chalcopyrite, they are at times slightly crinkeled or contorted in appearance (Fig. 1). Two or more sets of blades of pyrrhotite are often present in the same crystal of cubanite (Figs. 2, 3). The parallel blades (considered in three dimensions probably plates) of pyrrhotite within a crystal of cubanite all show the same orientation in polarized light, similar to the albite in perthite. Also as observed in polarized light the pyrrhotite blades are aligned in different directions in adjacent grains of cubanite. The blades of pyrrhotite commonly end at the margins of the cubanite crystals where the adjoining mineral is chalcopyrite. Some similar appearing blades of pyrrhotite are, however, also found in the chalcopyrite. An area of

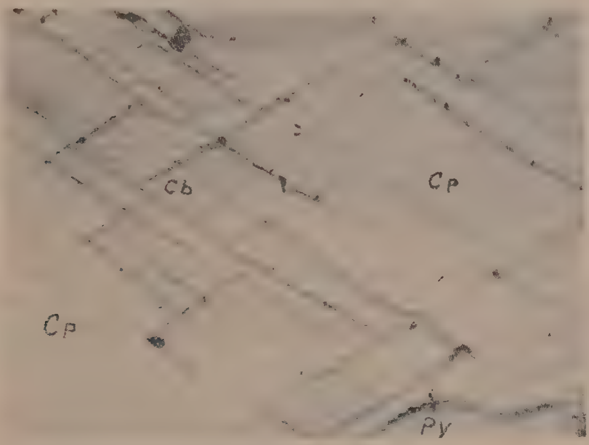

Fig. 1. (×210) Chalcopyrite-cubanite-pyrrhotite intergrowth. The chalcopyrite (Cp)-cubanite (Cb) laths are horizontal while the pyrrhotite (Py) forms two intersecting diagonal sets of crinkled blades. The blades of pyrrhotite join on a larger mass of pyrrhotite in the lower right corner of the figure.

mixed blades or laths of cubanite and chalcopyrite have the pyrrhotite in one, two or more rarely three sets of parallel blades, similar to the occurrence in cubanite alone (Fig. 1).

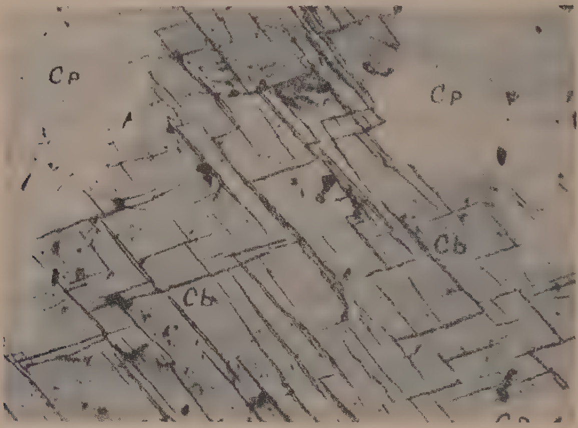

FIG. 2. (×68) An intergrowth partly surrounded by chalcopyrite (Cp). The intergrowth of cubanite (Cb)-chalcopyrite is mainly cubanite with small lighter colored laths of chalcopyrite in it. The pyrrhotite forms two sets of diagonal intersecting blades.

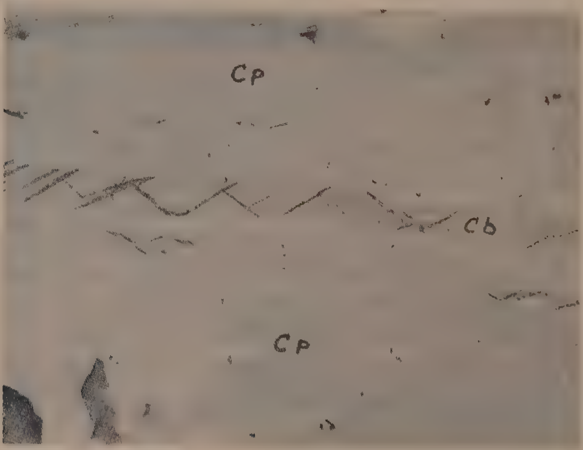

FIG. 3. (×68) A lathlike mass of cubanite (Cb) in chalcopyrite (Cp). Pyrrhotite forms two sets of blades in the cubanite. Two smaller parallel laths of partly resorbed cubanite with contained pyrrhotite blades appear above the main cubanite lath and one below it.

The pyrrhotite is usually more abundant in the intergrowths adjacent to the borders with magnetite, pyrrhotite and pentlandite.

At the junction with a large mass of pyrrhotite the blades of pyrrhotite frequently join or connect with the large mass of pyrrhotite (Fig. 1). They have a different crystal orientation than the large mass of pyrrhotite.

Pentlandite is often very thoroughly dissected by small veins of chalcopyrite.

SUMMARY AND CONCLUSIONS

The minerals appear to have been crystallized in the following order. Magnetite first in small subhedral to euhedral crystals well scattered in the sulphides, pyrrhotite next in irregular masses, then pentlandite, and finally a solid solution which apparently ranged from essentially pure chalcopyrite to one very rich in iron. The solid solution which was very rich in iron as compared with pure chalcopyrite, on cooling unmixed with the segregation of chalcopyrite and cubanite. The cubanite rich portions, such as the areas showing intergrowths of cubanite and chalcopyrite, and also individual laths of cubanite, unmixed to form cubanite and pyrrhotite. Occasional blades of pyrrhotite in chalcopyrite may be due to unmixing of iron rich chalcopyrite, but the evidence is not clear on this feature.

The pyrrhotite may not have all separated from solid solution at the same time. Some of it in the intergrowths of cubanite and chalcopyrite may have separated before the other two components.

There appears to be some later resorption, reforming of the solid solution or replacement of cubanite by chalcopyrite, as is shown by a variety of evidence chief of which is that laths of cubanite containing unmixed blades of pyrrhotite appear in all stages. One in which the cubanite lath with unmixed blades of pyrrhotite forms sharp straight borders with chalcopyrite, through others in which irregular portions interpreted as residuals, outline the former lath of cubanite, the pyrrhotite blades also outlining the former blade of cubanite (Fig. 3).

Final stages may be seen with blades of pyrrhotite forming exactly similar structures and little or no cubanite present (Fig. 3).

PROBERTITE FROM RYAN, INYO COUNTY, CALIFORNIA

William F. Foshag,[1] *U. S. National Museum.*

The mineral probertite was described by A. S. Eakle[2] as a new hydrous borate of soda and lime from the borax mines near Kramer, California. The mineral was independently described by Waldemar T. Schaller[3] under the name kramerite. At this locality it is one of the minor minerals of the borax ore and is found as radiating rosettes of thin blades or needles in low grade kernite, borax, or in the clay lenses that occur sparingly in the massive body of salts. There is no doubt that kramerite is identical with probertite although the analysis of Eakle's is apparently in error and leads to a formula somewhat different from that obtained by Schaller.

Before the discovery of the borax deposits near Kramer, Kern County, the colemanite deposits at and about Ryan, Inyo County, California, were the chief source of this commodity. The producing mines were the Biddy McCarthy, the Widow, the Played-Out, and the Annie Oakley. Colemanite was the chief ore mineral although in the Lower Biddy McCarthy mine important amounts of ulexite are present and in the Widow mine, besides ulexite, a mineral locally known as "*boydite*" (a name used in a descriptive circular of the Death Valley Region by the Union Pacific Railroad) is abundant and is said to have been shipped in some quantity as a borax ore. This mineral has also been found in lesser amounts in the Upper Biddy McCarthy mine. Investigation of this material shows it to be identical with probertite.

The mineral from the two mines differ slightly in their appearance, that from the Widow mine being in long, satiny, divergent needles or laths, some of these needles being as long as 30 centimeters. The luster is satiny, rarely glassy, and the perfect cleavage of the mineral is usually quite evident. The width of the cleavage faces, however, rarely exceed one millimeter. It also occurs as fibrous, closely reticulated aggregates and with a silky to greasy luster. The mineral is rarely transparent and is usually translucent. Probertite is associated with a light buff or pinkish indurated marl and sometimes with a soft bentonitic clay. The marl is in small broken blocks suggesting a breccia and the probertite forms interstitial and vein-like masses suggesting a secondary origin. In some portions of the deposit the probertite is purer but finer bladed, forming a tough compactly reticulated aggregate.

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[1] Published by permission of the Secretary of the Smithsonian Institution.

[2] Probertite, a new Borate: *Am. Mineral.*, **14,** 427–430, 1929.

[3] Borate Minerals from the Kramer District, Mohave Desert, California; *U. S. Geol. Surv., Prof. Paper* **158,** 137–170, 1930.

The probertite from the Upper Biddy McCarthy mine was not found in place but a considerable quantity was piled near the edge of the dump. It is finer bladed than the Widow mineral, somewhat laminated and with flattened radial structure or compact with a greasy luster. At times specimens can be found with a botryoidal surface suggestive of the massive ulexite of the colemanite deposits. The mineral is admixed with slight amounts of gray clay and occasionally shows small pebble-like concretionary masses of carbonate of lime, such as make up "conglomerate" beds in the colemanite-bearing sedimentary series.

Abundant material was available for chemical investigation, the sample prepared was selected from a pure mass of coarsely bladed needles. Boric acid was determined by titration in the presence of mannite with standard sodium hydroxide. The remaining constituents were determined in the usual manner after boric oxide had been removed by repeated evaporations with methyl alcohol and hydrochloric acid. The results are given below:

ANALYSIS OF PROBERTITE, RYAN, CALIFORNIA
W. F. Foshag, Analyst

	I	II
Lime (CaO)	15.88	15.98
Magnesia (MgO)	0.06	
Iron and aluminum oxides (Fe_2O_3, Al_2O_3)	0.38	
Soda (Na_2O)	9.00	8.83
Boric Oxide (B_2O_3)	49.10	49.56
Water (H_2O)	25.64	25.63
Insoluble	0.20	
Total	100.26	

This analysis agrees satisfactorily with those of Schaller for probertite and with the theoretical composition for the compound $Na_2O \cdot 2CaO \cdot 5B_2O_3 \cdot 10H_2O$. (Column 2). It is thus a lower hydrate of the ulexite series. The pyrognostics are like those described by Schaller. The mineral is insoluble in water but easily soluble in dilute acids.

Since the Ryan mineral is coarser bladed and more compact the hardness is greater than that found by Schaller for the Kramer material. The coarse-bladed mineral from the Widow mine easily scratches calcite but does not mar the smooth crystal surface of fluorite. It is therefore about $3\frac{1}{2}$ in hardness. The specific gravity, measured by the Jolly balance, using a pure compact fragment of mineral is 2.135. The cleavage is perfect, parallel to *m* (110), the interfacial angle of the cleavage faces measured 87° (ϕ for the prism *m* $(110)=43°30')$.

The mineral is biaxial, positive, and has a medium large optical angle (estimated 70°). Crystals lying on the pinacoid *a* show the emergence of an optic axis near the edge of the field and have parallel extinction. Crystals placed on end show the emergence of an optic axis in the field. The plane of the optic axes lies parallel to the pinacoid *b*. Crystals lying on the prism face show an inclined extinction, the maximum angle measured being 13°. The indices of refraction measured by the oil immersion method gave:

$$\alpha=1.517, \qquad \beta=1.525, \qquad \gamma=1.544.$$

These are essentially the same as those found for the Kramer mineral by Schaller and C. S. Ross. The optical orientation is: $Y=b$, $Z \wedge c=13°$.

There are embedded in the soft bentonitic clay many crystals of probertite but they are invariably deeply etched and corroded so that satisfactory crystal measurement is impossible. The form of the crystals is often distinct, however, and measurements were sufficiently good to identify the forms present. These are the prism *m* (110), the pinacoid *a* (100), rarely the domes *t* (101) and *e* (011). The habit found is similar to some on the kramer mineral. The crystals are usually small, seldom measuring more than 5 millimeters, the larger ones being so deeply corroded that their crystal form is no longer evident.

The central portion of the Widow ore body is made up of massive ulexite. The colemanite is best developed along the foot wall of the body but is also present to a lesser extent along the hanging wall. Probertite was found associated with the colemanite and its relationship to the ulexite could not be determined. The presence of an abundance of this lower hydrate presents an interesting problem while the higher hydrate, ulexite, is much more abundant and widespread in these deposits. Artificial probertite has been synthesized by Van't Hoff and also by Schaller by heating two parts of ulexite and one of borax to a temperature of 60°C. or higher. It is doubtful, however, if any temperatures even approximating this was attained in the boron beds. From the relationship of the mineral to the marl fragments it is quite evident that the mineral has undergone some rearrangement or recrystallization. Its general similarity to the ulexite of similar deposits suggest that probertite is a recrystallization of ulexite, the formation of the lower hydrate being favored by the pressure of the superincumbent load of sediments and lavas or by the pressure induced by earth movements. The appreciable difference of volume (ulexite: Sp. Gr. = 1.963; probertite: 2.141) would favor this change with increasing pressures.

NOTES AND NEWS

A NEW OCCURRENCE OF VIVIANITE IN VIRGINIA.

BENJAMIN GILDERSLEEVE, *University of Virginia*

During the latter part of June, 1930, while making a study of the Eocene formations in the vicinity of Fredericksburg, Virginia, fragmentary specimens of indurated greensands were collected from the Nanjemoy beds at Woodstock which contain radiating crystal aggregates of vivianite. Woodstock is an old homestead on the south bank of the Potomac River, 31 miles east of Fredericksburg, now known as Mathias Point, in King George County. At the time the collections were made nothing was known as to the nature of the mineral in question. The writer is indebted to Dr. C. S. Ross of the United States Geological Survey for its identification. No reference in the literature to such an occurrence in Virginia has been made so far as is known. Dana in his *System of Mineralogy* reports its occurrence in bog ore in Stafford County, and also as occurring 8 or 10 miles from Falmouth with gold and galena. He does not give any references so that apparently the occurrences which he cites have not been described.

The crystals of vivianite occur as acicular, radiating aggregates on the outer surfaces of the indurated greensand fragments. The individual crystals average 4 mm. in length, the maximum being 7 mm. Cleavage is well developed in the direction (010). In color the crystals vary from dark blue to bluish-green. Owing to the extreme scarcity of the crystals occurring at this locality, blow pipe tests have not been made of the specimens collected.

Vivianite is essentially a hydrous ferrous phosphate, $Fe_3(PO_4)_2 \cdot 8H_2O$; ($H_2O = 28.7$ per cent). Its composition suggests an association with glauconite which is a hydrous silicate of aluminum, iron, and potash.

Vivianite is mentioned as occurring in clays and marls in New Jersey and elsewhere, but its occurrence in indurated greensands in Virginia has not heretofore been described in the literature so far as is known.

A Correction

The foot-note reference on page 134, volume **16,** No. 4, should read: H. W. Foote instead of A. W. Foote and *Jour. Am. Chem. Soc.*, instead of *Am. Jour. Sci.*

BOOK REVIEW

HANDBOOK FOR PROSPECTORS, M. W. VON BERNEWITZ. Second edition. McGraw-Hill Book Company, Inc., *New York*, **1931**. XI+359 pages, 89 illustrations. Price, $3.00.

This book is written as a handy guide for prospectors and other men who, from time to time, may wish to undertake some kind of prospecting work. The author assumes that these readers have not had a basic training in mineralogy and geology and therefore attempts to present the subject matter in such terminology and simplified classification that the layman may readily understand it. In undertaking such a difficult task, however, he occasionally throws himself open to criticism by his professional associates, which in such an endeavor is almost an inevitable result.

One-half of the book is devoted to a discussion of the most common non-metallic and metallic minerals in reference to their occurrence, description, detection, use, value, etc. They are listed alphabetically for ready reference. Each mineral or metal is treated with special regard to its particular attributes and considerable supplementary material is added where appropriate, such as methods of prospecting, mechanical concentration, types of deposits, minerals which might be mistaken for the one in question, etc.

A short but good "glossary of terms used in mining" is included which contains many words not used in the simple discussions in the book but are intended, apparently, to aid the prospector in reading governmental, and other publications, so often referred to.

Because of the growing importance of geophysical methods of prospecting, a chapter in keeping with the general simplicity of the book has been included on this subject. It has as its object merely the familiarizing of the prospector with the various methods of geophysical prospecting and the opinions of experts regarding their utility.

The first third of the book is devoted to a series of twenty-six very short chapters which deal with the following subjects: financial aid to prospectors, equipment, food, water, transportation, mining laws, first aid, introduction to mineralogy and geology, occurrence of ores, outcrops, sampling, field tests, development of prospects, and markets and prices.

Aside from certain minor criticisms which might be mentioned such as: certain ambiguous expressions; improper designation of crystallographic forms and their orientation; and the antiquated treatment recommended for snake bites, the book contains many helpful suggestions to prospectors and should command a wide sale.

A. J. Eardley

PROCEEDINGS OF SOCIETIES

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences of Philadelphia, June 4, 1931

A stated meeting of the Philadelphia Mineralogical Society was held on the above date, Mr. Toothaker presiding. Mr. Strock announced his resignation as secretary of the society.

Mr. Morrell G. Biernbaum addressed the Society on *The Crystal Identification of Minerals*. The speaker limited his discussion to those points which are useful as a means of identification in the field. Introductory to his presentation Mr. Biernbaum gave an elementary description of the various crystal systems and common forms. It is frequently necessary to utilize certain peculiarities of crystal habit common to some minerals, in order to distinguish them from closely related species. Among these peculiarities may be mentioned, striations, etch figures, internal fracture, and cleavage.

Mr. Fleming Jr. exhibited excellent specimens of white stilbite, golden calcite and heulandite from the old Workhouse quarry at Moores Station, New Jersey. Mr. Hoadley described a visit to the dumps at Tilly Foster.

Dr. Newcomet exhibited some experimental results involving radiation. An exposure of X-ray films to powdered gas mantles, and to some radioactive minerals, showed that the radiation from the mantles is mostly superficial and has little penetrating power, whereas the radiation from radioactive minerals is chiefly "deep" radiation and has a high penetrating power. Mr. Vanartsdalen reported small vesuvianite crystals from a recent cut at New Hope, Pennsylvania.

Mr. Trudell announced the prize winners of the Northeast High School Mineralogical Exhibit, held May 20.

Sixty-four persons including forty-nine members were present.

Lester W. Strock, *Secretary*

NEW MINERAL NAMES

Nagatelite

Satoyasu Iimori, Jun Yoshimura and Shin Hata: A new radioactive mineral found in Japan. *Scientific Papers Inst. Phys. Chem. Research, Tōkyō*, **15**, No. 285, 83–88, 1931.

Name: From the locality, Nagatejima, a small headland on the Noto Peninsula.

Chemical Properties: A phospho-silicate of aluminum, rare earths, calcium and iron; $4RO\ 3R_2O_3\ 6(SiO_2, P_2O_5)\cdot 2H_2O$. Analysis: SiO_2 25.2, TiO_2 0.57, P_2O_5 6.48, Al_2O_3 14.3, Fe_2O_3 2.40, Ce_2O_3 14.58, La_2O_3, etc. 7.84, Y_2O_3, etc. 4.51, ThO_2 0.88, FeO 7.89, MnO 1.12, CaO 10.4, MgO 1.04, H_2O- 0.22, H_2O+ 2.35. Sum 99.97. Soluble in hydrochloric acid with separation of silica.

Crystallographical Properties: System not given but presumably monoclinic. Forms: $a(100)$, $c(001)$, $r(\bar{1}01)$, and $l(\bar{2}01)$. $a \wedge c = 64°$.

Physical and Optical Properties: Color black. Streak pale brown. Luster resinous. Brittle. Fracture uneven. Hd=5.5. G=3.91.

Biaxial. Axial plane parallel to b. $Bx_a \wedge c = 32°$. $\alpha = 1.750$, $\beta = 1.760$, $\gamma = 1.765$. Pleochroism: X brownish yellow, Y (greatest absorption) reddish brown, Z pale yellow.

Occurrence: Found in narrow pegmatite dikes in gneissic granite and diorite lying on the shore of Shibagaki, especially at Nagatejima, near the village of Kami-amada, Hakui County, Ishikawa Prefecture, as crystals 6–7 mm. long and 2–3 mm. across, or in tabular masses up to 15 mm. across.

A member of the epidote group related to allanite.

W. F. Foshag

Sérandite

A. Lacroix: Les pegmatites de la synénite sodalitique de l'île Rouma (Archipel de Los, Guinée française). Description d'un nouveau minéral (sérandite) qu'elles renferment. (The pegmatites of soda syenite of the island of Rouma (Los Archipelego, French Guinea). Description of a new mineral (sérandite) contained in them. *Compt. Rend., Acad. Sci. Paris*, **192,** no. 4, p. 187–194, 1931.

Name: In honor of M. Sérand, who assisted in its collection.

Chemical Properties: A hydrous silicate of manganese, calcium, sodium and potassium; 7.5 (Mn, Ca) O. 1. 5 $(Na, K)_2O$. $10SiO_2 \cdot H_2O$ $[(Mn, Ca, Na_2, K_2, H_2)$ O. $SiO_2]$. Analysis (by M. Raoult) SiO_2 48.72, Al_2O_3 0.29, Fe_2O_3 0.03, FeO 1.33, MnO 28.99, MgO 0.06, CaO 10.42, Na_2O 7.38, K_2O 0.26, H_2O+ 2.67, H_2O- 0.11; total 100.46.

Crystallographical Properties: Monoclinic. Crystals elongated parallel to the orthopinacoid zone. Two cleavages in the orthopinacoid zone. The angle $\phi(ca) = 85°30'$.

Physical and Optical Properties: Color rose red.

Biaxial positive. $2V = 35°30'$. Plane of the optic axes is normal to the plane of symmetry. Extinction of X with the edge of (100), about 57° in the acute angle. $\alpha = 1.660$, β about 1.664, $\gamma = 1.688$. Birefringence 0.035.

Occurrence: Found in nepheline syenite as a filling between feldspar laths, with sodalite, nephelite, astrophyllite, arfvedsonite, eucolite, leucophane, fluorite, sphalerite, molybdenite and aegyrite and later analcite, mesotype and villaumite

W. F. F.